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RESISTANCE TO COVERED SMUT IN VARIETIES AND HYBRIDS OF OATS[1]

E. F. GAINES[2]

INTRODUCTION

It is unfortunate that more practical use has not been made of the known facts of resistance of certain strains of cereal crops to their major parasitic troubles.

If more attention had been given to testing and introducing immune varieties as soon as such variations were known, the huge

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[2]Cerealist.

losses of recent years might have been much reduced. The losses in oats in the state of Washington alone due to loose and covered smut, *Ustilago avenae* (Pers.) Jens. and *U. levis* (K. & S.) Magn., have been approximately a third of a million bushels annually. This loss will probably soon be reduced, however, by the introduction of Markton oats, which, according to Stanton, Stephens, and Gaines (8),[3] is not only immune from smut but is also superior in yield in the Pacific Northwest. Between 50,000 and 100,000 bushels of Markton were produced in 1925. Schafer, Gaines, and Barbee (7) have tested this in comparison with many other varieties and conclude that Markton may be sown without seed treatment, will out yield other varieties, and is a superior milling variety.

This example serves to show the possibilities and the trend in recognizing the economic possibilities in combating plant diseases with resistant varieties.

Reed (4) in 1920 reviewed the work of earlier authors on the subject of comparative resistance of oat varieties to loose and covered smuts, and also presented the results of his tests with some 150 varieties at the University of Missouri. Of the seven host species studied, *Avena brevis* Roth. and *A. strigosa* Schreb, gave only smut-free plants. *A. byzantina* C. Koch was very resistant, but low percentages of infection were obtained on some of the varieties. The other species were generally susceptible, although but two varieties of common black oats proved immune from both smuts. Later, Reed (5) obtained covered smut from Wales that would attack both *A. brevis* and *A. strigosa* severely, although no smut was obtained on certain varieties of common oats that are considered susceptible in America. This is the first evidence of specialized races of oat smut and offers added complications in breeding for resistance. The fact that Black Mesdag and Fulghum were immune from both loose and covered smut in all of Reed's tests indicates that it is possible to obtain varieties that are immune to all races of smut.

Bartholomew and Jones (2) and Reed and Faris (6) have worked out the conditions of soil acidity and of moisture and temperature conditions which give optimum infection so that a uniform technic for testing the resistance of oats to both smuts is possible. In recent years most tests for resistance have been made with inoculated seed and under conditions that would produce heavy infection on susceptible varieties. This brings out in sharp contrast the inherent differences of the germ-plasm in controlling the disease.

[3]Reference by number is to "Literature Cited," p. 789.

Barney (1) has worked out the inheritance of resistance to loose smut in three different crosses of oats in which resistance was unmistakably dominant, but widely different ratios of resistant and susceptible segregates occurred in the different crosses. He suggested that certain resistant varieties carried one factor for resistance, certain others carried two, while others carried three independent factors, any one of which would cause resistance.

Wakabayashi (9) likewise found resistance to covered smut in a cross between Red Rustproof and Black Tartarian to be dominant, but caused by multiple factors.

VARIETAL RESISTANCE TO COVERED SMUT AT PULLMAN, WASHINGTON

Definite tests at the Washington experiment station at Pullman for resistance to covered smut with inoculated seed was begun in 1918. During the eight-year period 1918 to 1925, more than 200 varieties and selections have been tested. Each test consisted of a rod row containing from 40 to 70 plants, except in 1918 when the rows were 4 rods long. The seeds were uniformly blackened with smut spores before sowing. At harvest time the plants of each row were pulled and divided into three classes, *viz.*, smut free, partly smutted, and entirely smutted. The good and smutted panicles on the partly smutted plants were also counted. The percentage of smut on the partly smutted plants was multiplied by the percentage of partly smutted plants and the result added to the percentage of totally smutted plants. This gives the loss as a single figure and is comparable to the percentage obtained from a straight head count. The records of all these tests are presented in Table 1. The names, identification numbers, and source of seed are given for reference.

An examination of Table 1 shows that 17 varieties have been tested only one year, 91 for two years, 67 for three years, and 35 varieties for four or more years. With the comparatively low percentages of infection in most of the varieties and the wide variations from year to year, it is considered advisable to test a variety at least three years in order to establish its relative susceptibility with a fair degree of accuracy.

It must be kept in mind that the smut averages in Table 1 are not strictly comparable because they were not all obtained during the same years. Moreover, the hulless varieties, being unprotected by the lemma and palea, have a better chance to become infected. The table is valuable, however, within the limits of error and variability in showing the trend, and since it is the only record available of the resistance of many of these varieties, it is presented for reference.

TABLE 1.—*Comparative susceptibility of varieties of oats to covered smut tested at Pullman, Washington.*

Variety	C. I. No.	Wash. No.	Percentage of smut in								Average	Source of seed
			1925	1924	1923	1922	1921	1920	1919	1918		
Abundance	1192	759	36	5	—	9	20	12	38	31	22	Cowper's, Scotland
Abundance	—	1188	—	—	—	—	—	26	—	—	26	Lilly's, Seattle
Alaska	—	2398	22	2	0	—	—	—	—	—	8	Ottawa Canada
Albion	729	2081	—	—	—	—	8	9	36	—	18	Kansas 5208
Albion	729	2298	—	—	12	6	13	—	—	—	10	Iowa
American Banner	1949	2086	—	—	—	—	—	19	8	—	13	Nebr.
Archangel	1947	2300	—	—	—	7	9	—	—	—	8	Iowa
Aurora	831	2106	—	—	—	—	0	0	12	—	4	Kansas 5206
Banner	1191	764	43	8	—	7	24	30	38	30	26	Cowper's, Scotland
Banner	1934	1191	—	—	—	—	—	26	—	—	26	Lilly's, Seattle
Banner	—	2087	—	11	—	19	20	18	11	—	16	Colorado
Banner	—	2397	46	20	17	—	—	—	—	—	28	Ottawa 49, Canada
Banner	—	2454	39	17	—	—	—	—	—	—	28	Aeschliman, Almota
Big Four	—	1036	—	—	—	19	16	10	—	—	15	Pottraz, Waverly
Black	290	665	—	—	—	20	11	—	—	—	15	Garton's, England
Black Alaska	—	1023	—	—	—	—	—	33	18	13	21	Lilly's, Seattle
Black x Large Hull-less	290/278	665/680	—	—	—	—	—	93	74	76	81	Wash. Sta.
Black Mesdag	1877	2488	0	—	—	—	—	—	—	—	0	U. S. D. A.
Black x Sixty Day	290/165	665/661	—	—	—	—	—	10	—	—	10	Wash. Sta.
Black x Sixty Day	290/165	665/661	—	—	—	—	5	16	—	—	10	Wash. Sta.
Black x Sixty Day	290/165	665/661	—	—	—	—	3	27	—	—	15	Wash. Sta.
Black x Sixty Day	290/165	665/661	—	—	—	—	2	trace	—	—	1	Wash. Sta.
Black x Sixty Day	290/165	1180	—	—	—	—	33	25	41	56	39	Wash. Sta.
Black Tartarian	—	762	—	—	—	—	—	29	37	31	32	Cowper's, Scotland
Bonanza	—	2446	48	17	—	—	—	—	—	—	32	Albers', Seattle
Bountiful Black	—	1951	—	—	—	—	—	33	—	—	33	Cowper's, Scotland
Burt	—	1201	—	—	—	—	0	trace	—	—	trace	U. S. D. A.
Burt	—	2055	—	—	—	—	—	0	0	—	0	Nebr.
Burt	—	2056	—	—	—	—	—	0	0	—	0	Kansas 6093
Burt	—	2057	—	—	—	—	0	0	0	—	0	Kansas 6091
Burt	—	2058	—	—	—	—	0	0	0	—	0	Kansas 6090

Burt	—	2059	—	—	—	—	—	4	5	—	4	Kansas 5020
Burt	—	2060	—	—	—	—	—	28	16	—	22	Kansas 6052
Burt	—	2062	—	—	—	—	—	11	27	—	19	Kansas 6004
Burt	—	2063	—	—	—	—	—	14	25	—	19	Kansas 5220
Burt	—	2064	—	—	—	—	1	5	15	—	7	Kansas 6092
Burt (Light red)	—	2114	—	—	—	—	0	0	0	—	0	Texas 633
Canadian	444	742	—	—	—	—	—	52	77	64	64	Garton's, England
Canadian White	—	1210	19	10	—	28	15	22	—	—	19	McAlister, Canada
California Red	—	2100	—	—	—	—	—	2	0	—	1	Calif. 1003
Captain	—	2458	14	25	—	—	—	—	—	—	19	Cowper's, Scotland
Castleton Potato	1972	1957	—	—	—	—	—	38	—	—	38	Cowper's, Scotland
Chinese Hulless	298	686	95	74	—	—	96	95	66	99	87	U. S. D. A.
Chinese Hulless x Swedish Select	298/213	686/662	—	—	—	—	—	81	—	—	81	Wash. Sta.
Clydesdale	—	2303	—	—	28	13	10	—	—	—	17	Iowa
Conqueror	—	2297	—	—	—	—	12	—	—	—	12	Iowa
Crown	—	1955	—	—	—	—	14	31	—	—	22	Cowper's, Scotland
Crown (662)	—	2068	—	—	—	—	—	18	1	—	9	Montana
Crown	—	2460	12	2	—	—	—	—	—	—	7	Cowper's, Scotland
Culberson	—	2304	—	—	0	0	0	—	—	—	0	Iowa
Czar of Russia	1957	2125	—	—	—	—	12	10	4	—	9	Colorado
Dalmenny Abundance	—	1956	—	—	—	—	4	26	—	—	15	Cowper's, Scotland
Danish	1966	1034	—	—	—	12	7	9	—	—	9	Wills', N. D.
Danish Island	519	2094	—	—	—	—	10	21	15	—	15	Moro, Ore.
Daubeney	1928	1050	—	—	—	—	—	23	24	8	18	Barteldes', Colorado
Dryland	1193	767	—	—	—	—	32	24	—	—	28	A. Kol. Russia
Early Champion	1930	1058	—	—	—	—	—	28	—	—	28	Berry's, Iowa
Early Mountain	—	1033	—	—	—	—	—	17	—	—	17	Wills', N. D.
Early Mountain	—	2101	—	—	—	—	6	17	7	—	10	N. D. 2760
Eclipse	—	2111	—	—	—	—	—	3	20	—	11	Kansas 5216
Emperor William	—	2112	—	—	—	—	14	20	—	—	12	Montana
Extrareichster	1956	2123	—	—	—	—	15	15	5	—	12	Colorado
Fulghum	—	2030	—	—	—	—	1	0	—	—	trace	Kansas 5179
Fulghum	1962	2034	—	—	—	1	0	0	—	—	trace	Texas 765–18

TABLE I.—*Continued.*

Variety	C. I. No.	Wash. No.	Percentage of smut in									Source of seed
			1925	1924	1923	1922	1921	1920	1919	1918	Average	
Fulghum	708	2116	—	—	—	—	0	trace	trace	—	trace	Texas 782
Garton	—	2083	—	—	—	8	8	16	10	—	10	N. D. 2017
Garton (1–15–38)	—	2084	—	—	—	—	—	10	5	—	7	Minn. 406
Garton (1–15–17)	—	2085	—	—	—	—	8	8	17	—	11	Minn. 404
Garton Gray	—	663	—	—	—	—	39	21	64	61	46	U. S. D. A.
Giant	1926	766	—	—	—	—	13	34	—	—	23	A. Kol. Russia
Goldrain	—	2096	—	—	—	—	40	37	7	—	28	Montana
Golden Rustproof	1929	1055	—	—	—	—	0	0	—	—	0	Berry's, Iowa
Great Lakes	1959	2122	—	—	—	—	6	15	2	—	8	Colorado
Great Northern	524	2093	—	—	—	—	—	24	35	—	29	Moro, Ore.
Great Northern	—	2407	18	16	—	—	—	—	—	—	17	Lilly's, Seattle
Hero	1941	1958	—	—	—	—	—	30	—	—	30	Cowper's, Scotland
Hull-less	—	2445	96	76	—	—	—	—	—	—	86	Gurney's, S. D.
Idamine	1834	2329	21	28	9	16	13	—	—	—	17	Aberdeen, Ida.
Iowar	—	2305	—	—	—	2	0	—	—	—	1	Ames, Iowa.
Irish Victor (1–15–16)	—	2046	—	—	—	—	0	5	1	—	2	Minn. 358
Joanette	—	2331	0	0	0	0	0	1	—	—	trace	U. S. D. A.
June	—	2104	—	—	—	—	0	3	8	—	4	Nebr.
Kanota	—	2457	0	3	—	—	—	—	—	—	1	Kansas
Kherson	1198	1047	0	1	—	1	1	trace	3	—	1	Galloway's, Iowa.
Kherson	—	1049	—	—	—	—	0	4	—	—	2	Barteldes', Colo.
Kherson	—	2048	—	—	—	—	0	0	2	—	1	Nebr. 21
Kherson	—	2049	—	—	—	—	2	10	5	—	6	Nebr.
Kherson	459	2050	—	—	—	—	—	15	14	—	14	Moro, Ore.
Kherson	—	2051	—	—	—	—	11	27	28	—	22	Nebr. 5
Kherson	—	2052	—	—	—	—	1	1	7	—	3	Kansas 5212
Kherson	—	2053	—	—	—	—	—	trace	trace	—	trace	Colorado.
Kherson (1–15–17)	—	2054	—	—	—	—	—	17	11	—	14	Minn. 358
King	—	2461	9	7	—	—	—	—	—	—	8	Cowper's, Scotland
Large Hulless	278	680	96	63	—	—	—	100	95	98	90	U. S. D.A.
Large Hulless x Red Rustproof	278/2140	680/768	0	13	—	—	—	—	—	—	6	Wash. Sta.

Leader	1942	1959	—	—	—	—	24	29	—	—	26	Cowper's, Scotland
Liberty	—	2400	89	48	77	—	—	—	—	—	71	Ottawa, Canada
Ligowo	—	1088	—	—	—	—	—	26	19	36	27	Sapporo, Japan
Ligowo	—	2102	—	—	—	—	—	12	3	—	7	Montana
Lincoln	—	2076	—	—	—	—	9	19	29	—	19	N. D. 768
Lincoln (1–15–125)	—	2077	—	19	—	23	14	17	13	—	17	Minn. 505
Maine	1935	1197	—	—	—	—	8	43	—	—	25	Maine
Maine 340	—	2412	21	15	2	—	—	—	—	—	13	Maine
Markton	2053	2088	0	0	—	0	0	0	0	—	0	Moro, Ore.
Markton	—	2413	0	0	0	—	—	—	—	—	0	Moro, Ore.
Markton	—	2414	—	0	—	—	—	—	—	—	0	Waterville, Wash.
Menota (1–06–11)	—	2115	—	—	—	0	trace	trace	1	—	trace	Minn. 237
Michigan	1927	1053	—	—	—	—	14	34	—	—	24	Michigan
Minnesota Medium Early	1952	2109	—	—	—	—	0	1	4	—	2	Kansas 5207
Minnesota 26	—	2124	—	—	—	—	4	19	6	—	10	Colorado
Minnesota 281	—	2351	32	11	11	16	—	—	—	—	17	Puyallup, Wash.
Nasgaard	—	2452	27	0	—	—	—	—	—	—	13	Maribo, Denmark
Nava	—	2450	16	0	—	—	—	—	—	—	8	Maribo, Denmark
Nebraska 21	—	1946	—	—	—	—	0	0	—	—	0	U. S. D. A.
Nebraska Burt	—	2061	—	—	—	0	0	2	4	—	1	Kansas 5211
Nebraska Red Texas	—	2079	—	—	—	—	—	3	9	—	6	Kansas 5213
New Alberta	—	1057	—	—	—	—	—	16	—	—	16	Berry's, Iowa
New Era	1958	1323	—	—	—	—	7	12	—	—	9	Vogt, Langley
New Industrial	1953	2110	—	—	—	—	—	14	27	—	20	Montana
New Market	—	1948	—	—	—	—	8	23	—	—	15	Cowper's, Scotland
New Sensation	1932	1059	—	—	—	—	9	13	—	—	11	Berry's, Iowa
Nickolsons	—	2107	—	—	—	—	0	1	0	—	trace	Kansas 5179
North Finnish Black	—	2097	—	—	—	—	0	0	0	—	0	Calif. 1002
O. A. C. 3	1948	2065	—	—	—	—	—	40	7	—	23	Montana
O. A. C. 72	—	2066	—	—	—	—	8	11	2	—	7	Montana
O. A. C. 72 (1–15–83)	—	2067	—	—	—	—	0	0	1	—	trace	Minn. 500
Potato	1967	761	—	—	—	—	—	52	—	56	54	Cowper's, Scotland
Prince Royal	1936	769	—	—	—	—	5	13	—	—	9	Montana
Probstier	—	2301	—	—	4	13	11	—	—	—	9	Iowa

TABLE I.—*Continued.*

Variety	C. I. No.	Wash. No.	Percentage of smut in									Source of seed
			1925	1924	1923	1922	1921	1920	1919	1918	Average	
Probstier	1656	2372	46	28	25	27	—	—	—	—	31	U. S. D. A.
Probstier (awnless)	1069	2373	31	18	24	5	—	—	—	—	19	U. S. D. A.
Record	1940	1954	—	—	—	—	15	26	—	—	20	Cowper s, Scotland
Red Rustproof	2140	768	0	0	0	0	0	0	0	0	0	Gentry, Texas
Red Rustproof Fraziers	—	2033	—	—	—	—	—	0	trace	—	trace	Texas 765–19
Red Rustproof	1963	2035	—	—	—	—	—	0	0	—	0	Texas 765–17
Red Rustproof	458	2037	—	—	—	—	—	8	1	—	4	Nebr.
Red Rustproof x Black Tartarian	—	768/762	—	—	—	—	0	0	—	—	0	Wash. Sta.
Red Rustproof x Black Tartarian	—	768/762	—	—	—	—	0	0	—	—	0	Wash. Sta.
Red Rustproof x Black Tartarian	—	768/762	—	—	—	—	0	0	—	—	0	Wash. Sta.
Red Rustproof x Black Tartarian	—	768/762	—	—	—	—	0	0	—	—	0	Wash. Sta.
Red Texas	—	2080	—	—	—	—	0	0	0	—	0	Kansas 6095
Regenerated Swedish Select	—	756	—	—	—	—	—	14	—	—	14	Houston, Pullman.
Regenerated Yielder	1939	1953	—	—	—	—	4	23	—	—	13	Cowper's, Scotland
Richland	787	2082	—	—	—	2	1	2	12	—	4	Kansas 5209
Richland	786	2108	—	—	—	—	3	1	5	—	3	Moro, Ore.
Rurakura	—	2415	10	10	5	—	—	—	—	—	8	U. S. D. A.
Rurakura Rustproof	701	2036	—	—	—	1	0	trace	2	—	1	Texas 780
Rustless	—	1346	—	0	13	4	—	—	—	—	6	Aberdeen, Idaho
Rutlidge Prize	1200	1326	—	—	—	—	9	15	—	—	12	Kloninger, Washougal
Sandwich	1194	758	—	—	—	—	9	17	38	36	25	Cowper's, Scotland
Scotch	—	752	—	—	—	—	45	57	—	—	51	Cowper's, Scotland
Scottish Wonder	1931	1056	—	—	—	—	11	11	—	—	11	Berry's, Iowa
Shadeland Climax	1196	777	—	—	—	—	—	72	32	—	52	Puyallup, Wn. 57
Shadeland Climax	681	2105	—	—	—	—	—	17	27	—	22	Moro, Ore.
Siberian	635	2092	—	—	—	—	75	23	31	—	43	Moro, Ore.
Silver	—	2451	11	trace	—	—	—	—	—	—	6	Maribo, Denmark

Silvermine	—	741	—	—	—	—	10	16	24	25	19	U. S. D. A.
Silvermine	1195	776	—	—	—	7	27	15	—	—	16	Puyallup, Wn. 53
Silvermine (1–14–16)	—	2117	—	—	—	—	14	14	12	—	13	Minn. 337
Silvermine	—	2118	—	—	—	—	—	16	7	—	11	Colorado
Sixty Day	165	661	7	4	—	5	7	22	8	22	10	N. D.
Sixty Day	626	1348	—	1	12	2	—	—	—	—	5	Newell, S. D.
Sixty Day	—	2073	—	—	—	—	—	26	10	—	18	Nebr.
Sixty Day	—	2074	—	—	—	—	—	13	6	—	9	N. D. 666
Sixty Day (1–17–72)	—	2075	—	0	—	14	5	9	1	—	6	Minn. 261
Sparrowbill	443	2352	17	12	8	22	—	—	—	—	15	Puyallup, Wash.
Supreme	1938	1952	—	—	—	—	4	28	—	—	16	Cowper's, Scotland
Swalof Victory	—	2044	—	—	—	—	5	18	13	—	11	N. D. 2723
Swedish Crown	—	1183	—	—	—	25	7	10	—	—	14	Eslof, Sweden
Swedish Crown	—	2069	—	—	—	—	—	31	10	—	20	Colorado
Swedish Select	213	662	31	15	—	42	11	18	28	22	24	U. S. D. A.
Swedish Select	—	1061	—	—	—	—	7	19	—	—	13	Montana
Swedish Select	134–1	2070	—	—	—	—	—	39	29	—	34	Moro, Ore.
Swedish Select	—	2071	—	—	—	—	—	13	14	—	13	Nebr.
Swedish Select	—	2072	—	—	—	—	4	27	44	—	25	Kansas 5185
Swedish Select	—	2443	32	1	—	—	—	—	—	—	16	Albers', Seattle
Swedish Select	—	2447	33	0	—	—	—	—	—	—	16	Albers', Seattle
Swedish Victory	—	1184	—	—	—	—	7	15	—	—	11	Eslof, Sweden
Swedish Victory	—	1950	—	—	—	—	3	14	—	—	8	Cowper's, Scotland
Swedish Victory	—	2045	—	—	—	29	8	22	13	—	18	Colorado
Tartarian	—	2098	—	—	—	—	4	9	27	—	13	N. D. 388
Tartar King	1973	1980	—	—	—	—	—	14	—	—	14	Swab, Dalkena
Texas Red	—	2078	—	—	—	—	0	0	3	—	1	Nebr.
Texas Red Rustproof	—	2038	—	—	—	—	8	33	2	—	14	Texas 1118
Three Grain	1950	2095	—	6	—	6	5	3	14	—	7	Moro, Ore.
Victory	—	780	—	—	—	—	—	—	40	23	31	Vermilion, Alta.
Victory	1197	1028	—	—	—	—	14	22	—	—	18	Lilly's, Seattle
Victory	—	1185	—	—	—	—	—	16	—	—	16	Lilly's, Seattle
Victory	—	1187	15	24	—	20	10	18	—	—	17	Lilly's, Seattle
Victory (111–17)	—	2039	—	—	—	20	10	23	10	—	16	Minn. 514

TABLE I.—*Concluded.*

Variety	C. I. No.	Wash. No.	Percentage of smut in									Source of seed
			1925	1924	1923	1922	1921	1920	1919	1918	Average	
Victory (404)	—	2040	—	—	—	—	—	38	4	—	21	Montana
Victory (Wheeler)	—	2041	—	—	—	—	5	31	4	—	13	Montana
Victory	—	2042	—	—	—	34	7	21	31	—	23	Moro, Ore.
Victory	—	2043	—	—	—	—	8	33	8	—	16	Montana
Victory	—	2047	31	20	—	27	8	21	43	—	25	Kansas 5210
Victory	—	2399	26	11	19	—	—	—	—	—	19	Ottawa, Canada
Victory	—	2459	13	15	—	—	—	—	—	—	14	Cowper's, Scotland
Vilmorin Black Hybrid	—	2306	—	—	—	24	1	—	—	—	12	Iowa
Waverly	1937	1949	—	—	—	—	—	17	—	—	17	Cowper's, Scotland
Welcome	—	2121	—	—	—	—	12	22	3	—	12	Colorado
Western Wonder	1951	2103	—	—	—	—	24	9	31	—	21	Moro, Ore.
White Belgium	1933	1090	—	—	—	—	9	24	—	—	18	Sapporo, Japan
White Liberian	—	2099	—	8	—	13	18	24	20	—	17	N. D. 864
White Russian	441	739	—	—	—	—	5	5	—	—	5	U. S. D. A.
White Russian	—	2113	—	—	—	—	—	19	7	—	13	Colorado
————	1960	2089	—	—	—	—	0	0	2	—	1	Texas 776
———— 511–11–7	—	2090	—	—	—	—	—	0	0	—	0	Texas 775
———— 518–37	—	2091	—	—	—	—	trace	4	1	—	2	Texas 777
————	1954	2119	—	—	—	—	20	17	5	—	13	Colorado 37
————	1955	2120	—	—	—	—	—	23	6	—	14	Colorado 13

All averages have been placed in ten classes in the first line of Table 2. The majority of the varieties fall in the three classes of 8, 15.5, and 25.5 % of smut, with decreasing numbers in the more susceptible classes.

For the most part, the immune and resistant classes belong to the Burt and Red Rustproof groups. The more resistant classes are usually of Kherson or Sixty Day type. The Hulless and Common groups are generally susceptible, the outstanding exceptions being the three Markton selections and the four Red Rustproof-Black Tartarian hybrids which are immune.

INHERITANCE OF RESISTANCE TO COVERED SMUT

Red Rustproof (*A. byzantina* C. Koch), because it has been immune in all tests even when the hull is removed, is considered genetically immune and unaffected by smut under all conditions. It has been crossed on several varieties of cultivated oats and the F_3 generations of four of these crosses have been tested in respect to resistance. Some difficulty was experienced on account of partial sterility and difference in time of ripening, but after eliminating the segregates that produced less than 10 plants there are still more than 800 F_3 families averaging more than 25 plants per family on which to base conclusions regarding the mode of inheritance of resistance. The conclusions are further strengthened by the tests of more than 100 F_4 selections. The F_3 and F_4 hybrid families have been grown in rod rows and given similar treatment, and the percentage of smut was obtained in the same manner as that described for the variety tests. No significant difference was obtained in reciprocal crosses and therefore they have been added together regardless of which way the cross was made, although in most cases Red Rustproof was used as the pistilate parent.

The average resistance of the four susceptible parents in 1918 to 1920, according to Table 1, is as follows:

Black Tartarian, *A. sativa orientalis* L.	32% smut
Abundance, *A. sativa* L.	22% smut
Large Hulless, *A. nuda* L.	90% smut
Chinese Hulless, *A. nuda* L.	87% smut

Black Tartarian is a widely known black side oat. The seed of this particular variety was obtained from Henry Cowper & Sons, seedsmen of Montrose, Scotland. Abundance, a prolific white tree oat of Silvermine type, was obtained from the same source. The two hulless varieties came from the United States Department of Agriculture about 20 years ago. They may be distinguished from

each other by the brown palea of Chinese Hulless, the palea of large Hulless being white. Genetically, Chinese Hulless is black (3) but no pigment occurs in the lemma except occasionally a streak along the midrib. In crosses with white or red hulled varieties, however, black hulled segregates occur in F_2 on about 75% of the hulled plants. The lower amount of smut in Chinese Hulless is apparently due to some error in infecting the seed in 1919 as there was no significant difference between it and the Large Hulless the other four years. Abundance appears to be somewhat less susceptible than Black Tartarian, but the plants from inoculated seed evidently escape infection about two times out of three.

The summarized results of the variety test of the parents and of the various hybrid families are given in Table 2.

The families which produced no smut were put in the immune class. If smut was found, the percentage in terms of the whole row was determined, and it was placed in its proper group. The resistant segregates were divided into smaller classes than those with larger amounts of smut in order to emphasize small differences nearest the immune class. The more susceptible a strain is, the wider the percentage of smut will fluctuate, due to external conditions. It is probable that the large number of immune segregates differ widely in their potential resistance, but other means must be devised for measuring it. The surprising and outstanding thing in all four crosses is the large number of immune segregates. There are evidently three dominant, independent factors, any one of which prevents the occurrence of covered smut, in hulled crosses. There are too many F_3 rows producing smut in the hulless crosses, however, for the assumption of complete dominance of three factors. If two factors, each completely dominant and a third factor intermediate for resistance on hulless segregates are operating, the results would very nearly fit the theoretical expectation.

Any multiple factor hypothesis would necessitate the assumption of varying intensities of resistance among the immune segregates. Let ABC represent three independent factors, any one of which would produce an immune oat. The segregate containing ABC would be more likely to resist attacks of new physiologic races, if such appear, than a segregate with only A or BC. Or, in crop improvement work, it would be much easier to combine immunity with other desirable economic qualities if three factors were present in the resistant parent.

Large and Chinese Hulless are so much more susceptible than Black Tartarian or Abundance that it is not surprising to find a

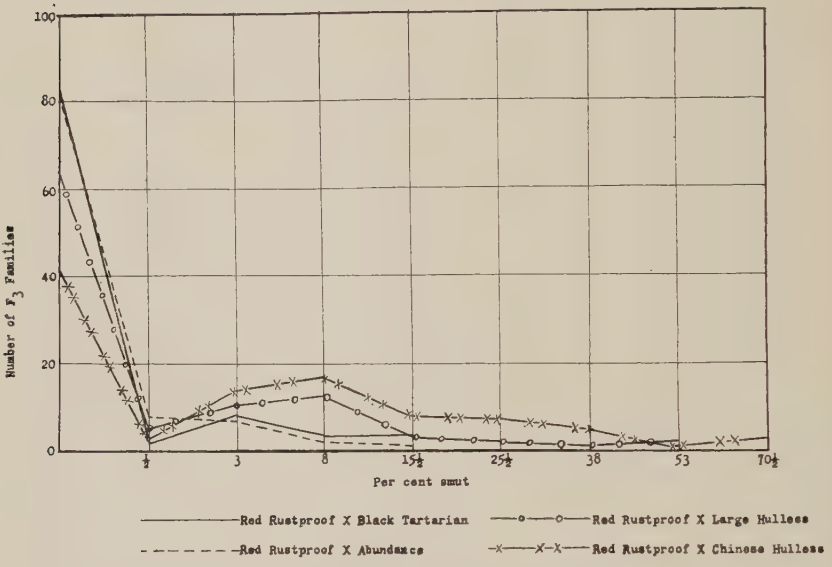
TABLE 2.—*Comparative susceptibility of oats to covered smut, Ustilago levis* (K. & S.) Magn., *parents and hybrids—all tests—1918–1925.* The percentage of smut produced from 0 to 100 has been arbitrarily divided into ten classes. The size of each class increases by an arithmetical progression of 2.5. This has been done to magnify small differences of the resistant segregates.

C. I. No.	Variety	Class centers, percentage covered smut										Total families
		0	0.5	3	8	15.5	25.5	38	53	70.5	90	
	All varieties (8 yr. test)	21	20	13	40	64	34	7	4	2	5	210
2140	Red Rustproof	18	—	—	—	—	—	—	—	—	—	18
762[a]	Black Tartarian	—	—	—	—	—	2	3	—	1	—	6
1192	Abundance	—	—	1	1	3	3	1	—	—	—	9
278	Large Hulless	—	—	—	—	—	—	—	—	2	5	7
298	Chinese Hulless	—	—	—	—	—	—	—	1	5	8	14
	Red Rustproof F_2 x Black Tartarian	2	—	—	—	—	—	—	—	—	—	2
	Red Rustproof F_3 x Black Tartarian	49	1	5	2	2	—	—	—	—	—	59
	Red Rustproof F_4 x Black Tartarian	4	—	—	—	—	—	—	—	—	—	4
	Red Rustproof F_5 x Black Tartarian	4	—	—	—	—	—	—	—	—	—	4
	Red Rustproof F_3 x Abundance	278	27	23	7	2	—	—	—	—	—	337
	Red Rustproof F_4 x Abundance	16	—	1	1	—	—	—	—	—	—	18
	Red Rustproof F_3 x Large Hulless	62	5	10	12	3	2	1	2	—	—	97
	Red Rustproof F_4 x Large Hulless	25	1	2	1	—	3	1	—	1	—	34
	Red Rustproof F_3 x Chinese Hulless	88	5	31	36	18	16	11	3	5	—	213

[a]Washington Number.

greater amount of smut in the F_3 segregates of the Red Rustproof-Hulless crosses. This is shown in Fig.1 where each class of the four F_3's have been reduced to a percentage basis for direct comparison.

Fig. 1.—Comparative susceptibility of F_3 oat hybrids to Ustilago levis. The inheritance is similar in all four crosses. The hulless segregates produced more smut because they had no hull to protect them.



Comparing the F_3 generation of Red Rustproof x Abundance with Red Rustproof x Chinese Hulless, it will be seen that the former is much more resistant throughout, having 82.5% of immune families compared with 41.5% for the latter. The general shape of the two curves are very similar, however. The difference is largely one of degree.

It is outside the province of this paper to discuss the inheritance of hullessness, red glume color, awns, lemma base and color, or date of heading, but it is evident that there is no clear cut case of linkage between smut resistance and any of these characteristics. One segregate of hulless type has been smut free in all tests through the F_3, F_4, and F_5 generations.

SUMMARY

1. Of 210 varieties and selections of oats tested for resistance to covered smut, *Ustilago levis* (K. & S.) Magn., during the past eight years, 21 were smut free, the others ranging from slight infection to extreme susceptibility in which nine-tenths of the panicles were black masses of smut spores.

2. Markton, one of the immune selections, is a thin hulled, white oat of *sativa* type, and is one of the best yielding varieties tested in recent years. It has been increased and grown commercially since 1924.

3. The inheritance of the immunity of Red Rustproof has been studied in four crosses with susceptible varieties. The crosses with Black Tartarian and Abundance indicate that Red Rustproof carries three dominant factors for immunity, any one of which prevents the production of covered smut spores. In crosses with Large and Chinese Hulless, one factor apparently does not give complete dominance in hulless segregates, but otherwise the prepotency of the factors for immunity is similar in all four crosses.

4. Of 56 F_3 plants selected from smut-free rows, 45 produced only smut-free plants in the F_4 generation.

5. From the results already obtained in varietal testing and breeding for disease resistance in field crops, it is to be hoped that the major diseases will in time be successfully controlled by the development and introduction of resistant or immune varieties.

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